

**Cold Roofing and Waterproofing Systems In The United States:
An Independent Overview of their
Performance Characteristics, Material Analysis and Solutions
for Proper Application
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Abstract

Cold-applied roof and waterproofing systems have been available in the U.S. roofing and waterproofing markets for more than 50 years. These systems were primarily designed to eliminate concerns associated with hot bitumen application by substituting asphalt cutbacks for the hot-mopped bitumen as the interply and surfacing bitumen. Although variations of these systems have been used in the United States for many years, they have never seriously contended with hot-applied built-up roof (BUR) systems for market share. Predominately, the use of cold-applied systems has been restricted to repair and maintenance of hot-applied built-up systems.

In recent years, the market share of these systems has expanded because of increased environmental regulations of hot-applied systems, new material developments and technology, and an ascent of situations where conventional systems prove impractical. This growth trend is expected to continue.

This paper will analyze the performance characteristics of these types of systems based on independent testing and available historical data. The main characteristics analyzed will be waterproofing capabilities, anticipated service life, strength characteristics and durability. Independent testing will be conducted on samples removed from existing applications in different U.S. geographic locations and a range of system ages. The criteria testing established to determine the waterproofing ability of these systems will be: visual observation, microscopic examination, tensile and elongation tests, test-cut analysis, water tests and accelerated weather tests.

The advantages and disadvantages of these systems will be presented with recommendations and solutions for proper application procedures.

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Preface

In 1999, we began an independent study of cold roof systems (cold-process and cold-applied) to determine the long-term performance characteristics of these types of systems. The initial phase of the study, completed between 1999 and the fall of 2000 was conducted through laboratory analysis of material samples constructed for the evaluation. Material samples were composed of cold-process systems with solvent-based adhesives, cold-process systems with water-based adhesives and cold-applied systems. The testing procedures and test results are published within this report.

The second phase of the study is a field investigation of completed cold-process and cold-applied systems. All types of cold roof systems older than five years were investigated to establish performance capabilities of completed applications. Representative systems were solicited from press releases in industry publications. Several manufacturers and roof construction companies provided past projects for us to investigate for this study. As part of the study, we have investigated cold roof systems in several geographic climates throughout the United States; including the Northeast, Southeast, Midwest and Southwest. The investigated roof systems were analyzed for defects, performance capabilities, weathering issues and waterproofing capacity. The results of these investigations will be presented at the XIIth International Roofing and Waterproofing Conference in Orlando, Florida, USA, Sept. 25-27, 2002.

Introduction

Briefly defined, cold-applied systems are described as waterproofing or roofing applications that use cold adhesives (solvent-based or water-based) in the adherence or fusion of felt. It generally refers to any application that is not torched or mopped down. Adhesives take the place of hot mopping or torching down membrane plies in the field of a roof.

The industry generally categorizes these systems in two distinct segments:

1. Cold process
2. Cold adhesive

Cold-process systems consist of multiple plies of reinforcement sheets that are set in a cold adhesive. These systems are often referred to as cold-process BUR systems because the application procedures are similar to hot applied BUR systems. The most common reinforcement felts are manufactured from fiberglass or polyester, which is either stitchbound or spunbound. Cold-applied systems utilize modified bitumen sheets (SBS most commonly or APP) in which the adhesive's primary function is the fusion of the sheets.

These systems are not new to the U.S. market. The first BUR systems were actually contrived of a cold-process system. In these early applications, pine tar was applied to glue roofing fabric together. These applications were also prominent in the United States in the early 1900s during the height of the railroad expansion. Solvent-based asphalt adhesives were sent on rail cars to remote areas for application of roofing felt with trowels and brushes. In later years, mineral-surfaced sheets were applied in medium viscosity asphalt mastics, which produced roof systems that were capable of providing weatherproofing for a number of years.

During the past 50 years, the market share of cold-applied systems has rarely risen above 5 percent compared with hot-applied BUR systems. Because of their low volume of full system applications, cold-process materials have been predominantly regulated to, and thought of as, repair and maintenance materials. Their low market share compelled major manufacturers to emphasize the larger market-driven systems and materials.

Although market gains were made in these applications during the 1970s, the removal of asbestos from mastics in the early to mid-1980s squandered the growth cycle. The removal of asbestos forced manufacturers to use substitute fibers, which resulted in deficiencies, such as slippage of the reinforcing sheets and fire-rating problems. These deficiencies, coupled with the advent of modified bitumen and single-ply roof systems in the U.S. market, propelled cold-applied materials back to the status of repair materials.

It should be pointed out that though the market share of these systems has been minimal, there are several "smaller" roofing and waterproofing manufacturers in the U.S. market that have manufactured cold-applied materials that are applied in system configurations. Many of these manufacturers, still in existence, have provided these materials (with variations) in full system applications for the past 50 years. This may speak to the longevity capabilities of these types of systems.

In recent years, the market share of these systems has expanded because of increased environmental regulations of hot-applied systems, new material developments and technology, and an ascent of situations where conventional systems prove impractical. Current U.S. industry data indicates that nearly 10 percent of all BUR and modified bitumen systems were cold-applied. This growth trend is expected to continue.

This growth spurt has resulted in an increased use of these systems by contractors who were more accustomed to built-up and torch-applied applications. It has also led to increased attention from manufacturers to provide materials to meet market demands. In some cases, both parties are entering uncharted territories. As with all roofing and waterproofing applications, it is important proper materials be applied within proper application requirements.

Advantages of Cold-Applied Systems

In recent years, there has been an increase in the use of cold-applied roof and waterproofing systems in the United States. Recent studies indicate that these systems may compose nearly 10 percent of the overall roofing market. These rates have doubled during the past 10 years. The increased usage of these materials as roof and waterproofing systems can be attributed to three diverse segmented advantages: economic factors for contractors; environmental, health and safety issues; and constricted applications.

Economic Factors for Contractors

Cold-applied systems are typically constructed as multiple-ply configurations with a sheet installed in liquid or cold adhesive. The similarity of these application methods to BUR systems ignites a steady stream of comparisons between the systems. The comparisons generally relate to application methods with proponents of cold-applied systems indicating that there are several advantages to the applicator over BUR systems. These advantages to roofing and waterproofing contractors could translate to economic benefits for contractors (i.e., higher profit margins).

One significant advantage is that very little equipment is required in the application of the cold-applied systems. Most of the work can be completed with squeegees, trowels and brooms. Many cold adhesives can be applied with spraying equipment, which further reduces labor costs and simplifies the installation process. Small work crews can be employed; oftentimes, crews of three to four workers are all that is required to complete substantial amounts of work on a daily basis. The increased rate of application can be attributed to ease of application and the fact that there is no significant downtime. Application rates increase as set-up time, equipment take-down time, equipment malfunction and idle time waiting for proper material heating (BUR systems) are eliminated.

As with all roof and waterproofing systems, the success of the system is based on a large extent on proper application methods. The relative ease of application with these systems promotes quick and efficient worker training. Although these materials can be improperly applied, they do not rely on workmanship as much as BUR systems. There is no underheating or overheating of the materials, and the materials tend to be forgiving of inaccuracies. Because of the curing process (which can be time consuming depending on weather), improperly applied sheets can be adjusted by the applicator during the installation process. This can reduce the costs of maintenance and repair that are often required in correcting initial application process. In contrast, the curing time and the sensitivity of the materials could be burdensome in colder climates.

Work with these systems is primarily clean and physically easier than BUR systems; the weight of a squeegee is far less than that of a hot mop, which could eliminate high employee turnover. As we enter a new millennium, one of the most pressing issues facing the United States is worker shortages in the construction trades, particularly in

the roofing and waterproofing trades. Obviously, these shortages are not limited to system application conditions. However, the availability of clean, easily applied and physically complimented systems could have a greater effect on attracting new workers to this industry in the future.

Environmental, Health and Safety Issues

Cold-applied systems are available that are free of asbestos, flammable solvents and odors. It is widely known that hot-applied bitumen (coal-tar and asphalt) BUR systems have been carefully scrutinized in the past decade for environmental issues. Occupational Safety and Health Administration (OSHA) classified coal tar as a human carcinogen in 1969. Although this classification is based on long-term exposure, its worldwide use as a roofing and waterproofing material has declined during the past 20 years. Coal-tar use has been all but eliminated in Canada and Europe, and its predominant use in the United States has been limited to less than a quarter of the states. The exposure rates of asphalt are still being investigated. The concerns associated with these products are in the heated state and from exposure of the smoke that heat produces.

More building owners are requiring that no kettles or hot-applied bitumen materials be installed at their facilities. Facilities sensitive to bitumen fumes would include hospitals, schools and heavily populated facilities. Typically, hot-applied projects are completed at industrial facilities during production shutdown times to eliminate employee empathy toward fume odors and the threat of bitumen drippage into the facility. These constraints limit the amount of work that can be completed at a facility during the course of a year.

The limits of hot bitumen usage are being imposed as much for safety reasons as environmental and health issues. Bitumens are applied at temperatures in excess of 400° F. The installation of cold-applied adhesives eliminates the requirement to heat and melt the bitumen and removes all fire and burn hazards from bitumen or torches. It also eliminates the placement of potentially dangerous propane tanks from the construction site. Most cold-applied adhesives are free of all flammable solvents and pose little fire hazard risks.

Constricted Applications

A major advantage of cold-applied systems is that they are assessable in tight, constrained areas. Areas with substantial amounts of equipment, particularly low-profile equipment, are suitable for cold-applied systems because of the hindrance of any other type of installation. Workers can access these cluttered areas without the safety risks related to hot bitumen or torches. High-rise buildings are also well-suited for cold-applied systems. The advantages of these types of installations is that spraying and pumping equipment can be placed right on the roof, reducing hose lengths and easing job requirements. Providing bitumen at proper temperatures on high-rise facilities is difficult and costly in the setup and project completion phases.

The increased attention that cold-applied systems have generated recently in the United States has led to a plethora of industry and manufacturer articles and papers outlining the advantages of these systems. The true intention of this paper is to analyze the performance characteristics of these systems in relationship to their waterproofing capacities as their true validity and is not based on their advantages promoted by the industry. However, in the context of background regarding these systems, the following outline of further advantages as presented by manufacturers and contractors is outlined:

- Minimal application equipment
- Easy delivery and storage at the job site
- Smaller crews that can be easily trained are all that is required, resulting in lower labor costs
- Reduced setup time and no premelting of bitumen
- Equipment removal is minimal
- Higher safety rates as a result of no open flames or hot kettles
- Repositioning of improperly applied sheets
- Ease of application in complicated, equipment-laden areas
- Environmentally safe application

Disadvantages of Cold Applied Systems

Conventional roofing pundits dismiss cold-applied systems as merely repair and maintenance procedures. Although these systems have evolved in the recent decade, their proportionately low market share during the past 50 years to 70 years negated the proper applicator training that is required for successful applications. Improperly formulated adhesives (to some extent) and improper application procedures (in large degree) contribute to system failures. The resistance of the roofing and waterproofing industries to accept these materials as valid systems has resulted in one of the primary disadvantages.

The major manufacturers were dictated by market share, which regulated cold-applied systems to be distributed as repair, maintenance and commodity products. The manufacturers that provided these materials as systems were typically smaller companies that operated within niche markets. Typically, these manufacturers worked with a select group of applicators that completed a majority of their applications. This presented several disadvantages to the vast majority of roofing and waterproofing contractors, including:

- Lack of supplier/manufacturer support
- Lack of technical knowledge of the materials
- Inadequate contractor experience with the materials
- Inadequate equipment to perform the applications
- Absence of manufacturers, warranties or guarantees
- Past product failures

These issues, in addition to contractors' reluctance to change from time-tested proven systems with which they were making money, negated market growth and became a disadvantage of these materials.

Ironically, one the advantages of cold-applied systems may also be a disadvantage. The relative ease of application and the labor savings that may be provided has initiated a growing trend of applications completed by inexperienced applicators. In some instances, building owners, in an effort to save costs, have assembled their maintenance personnel to apply these materials. More often than not, these applications failed because of a lack of proper training, supervision and the basic understanding of how to properly apply these materials.

Another of these systems, disadvantage is weather constraints. Although all roof and waterproofing systems face weather constraints, imminent failure is more probable with cold-applied materials. An applicator must have knowledge of the weather constraints of the materials and allotted curing time. It is imperative the materials are not applied when there is a chance of precipitation or inclement weather. Some adhesives and coatings may wash away if they encounter precipitation before properly curing. The temperature restrictions may also prohibit an applicator from working on a day other systems may be applied.

Although these systems are relatively easy to install, the proper installation procedures must be completed for successful application. Some more common application errors include the following items:

- Entrapment of moisture in the insulation or membrane
- Inadequate or excessive use of adhesives and/or coatings
- Failure to properly set reinforcement sheets in the adhesive
- Improper preparation of the substrate or insulation
- Application of materials in weather conditions that are not suitable for application
- Some coatings have a tendency to peel in ponded water

Differences Between Cold-Applied Systems and Hot Bitumen Systems

In built-up roof systems, the hot bitumen is the waterproofing agent and the felt is the stabilizer. In contrast, adhesives used in cold-applied systems provide little waterproofing capacities and require either a waterproof base layer or a waterproof membrane. The basic difference of these materials is in their chemical properties.

Asphalt is a thermoplastic material, which changes properties with an increase in temperature. The material turns to a liquid state as the temperature increases. Further temperature increases result in decrease of viscosity, which thins the material. As the membrane is applied to the hot asphalt, the asphalt cools and solidifies and the curing process and subsequent waterproofing protection begins immediately. Total cure time is approximately two to three hours.

Cold-applied adhesives contain solvents that must evaporate to provide a solid or cured state. The solvent evaporation process, or flashing as it is commonly referred to, depends in a large degree to the rate of material application and ambient weather conditions over time. The system adhesion increases as the solvent evaporates. The most important aspect of a cold-applied system is that it must properly cure. Once cold-process materials cure, there is no change in their properties. In theory, once a material cures and the volatiles are out of the product, it forms a continuous layer that does not change its properties and should not wear out. Asphalt, on the other hand, crystallizes over time as oils dissipate and the material becomes brittle, reducing its waterproofing ability. If properly formulated, a cold-applied adhesive can achieve a significant set of qualities over hot bitumen. The properties of cold-applied systems should be better than hot asphalt because of the thinner film application.

Cold-Applied Materials

The main function of an adhesive is to promote the adhesion or bonding of the reinforcement. A proper adhesive should not have an effect on the performance of the reinforcement. The bonding mechanism occurs as the adhesive dries to a thin film as the solvents evaporate.

Adhesives for cold-process systems are classified in two categories:

1. Solvent-Based Adhesives
2. Water-Based Adhesives

Solvent-Based Adhesives

The most common types of cold-process adhesives are solvent-based adhesives. These products are generally asphalt cutbacks, which are manufactured by adding solvents, such as mineral spirits, and varnishes, to asphalt that have been heated to 150°F to 200°F. The asphalt is heated to this temperature to make the asphalt fluid while maintaining enough heat to evaporate the solvents. Mastics and roof cements are manufactured by adding asphalt, solvents and an organic filler, such as cellotuse.

There are currently environmental concerns regarding the use of petroleum solvents in cold-process adhesives. In some parts of the United States, regulations have been imposed on the use of volatile organic compounds (VOCs). This has led to the reduction of solvent content in the adhesive, which can produce a material that is too thick to spread well. Solvent-based products can be applied over a wide range of temperatures, including cold or marginal weather conditions. These adhesives cure quickly under conditions of high humidity.

Volatile Organic Substances (VOS)/Volatile Organic Compounds (VOC) Regulations

The elimination of asbestos in cold adhesives forced manufacturers to explore viable alternatives to strengthen the quality of the material. Asbestos substitutions were generally additional solvent fillers. Recently imposed regulations in the United States delayed the advancement of solvent-based cold-applied adhesives. The regulations limit the release of VOC and VOS into the atmosphere. The release of airborne volatiles occurs as the regulated chemicals are exposed to sunlight, releasing a photochemical smog.

Although there are other ingredients in cold-applied adhesives that emit organic compounds into the air, the solvents in the formulations account for a vast majority of the released emissions. The regulations have forced manufacturers to develop adhesives that meet these requirements and still provide the essential properties to perform to their full capacities. The current regulations have set back the development of cold-applied adhesives at least five years.

Some common solvents used in the formulations include mineral spirits, naphthas, alcohols, xylene, toluene and chlorinated compounds. In addition to the VOC/VOS regulations, some solvents are also highly toxic and usually flammable. Transporting these materials can be cumbersome, and caution is required in the handling procedure. The U.S. Department of Transportation has classified certain materials as "red label" products because of low flash points. It is important an applicator is properly trained and exercises care in the handling, storing and application of these materials.

Notwithstanding the drawbacks, solvents are critical components in cold-applied adhesives. That is why manufacturers have diligently worked to compose formulations that contain the proper amount of solvents to meet the regulations and still provide the required adhesive properties. Solvents provide a variety of important functions in the adhesives, including the following items:

- Solvents improve the adhesion to substrates by allowing for better wetting of the surface.
- Solvents aid in the packaging and transfer of the finished products.
- The amount of solvents in the product correlates with the application procedures; low solvent adhesives are thicker and troweled in place and high solvent materials are lighter and can be sprayed or brushed in place.
- Solvents unite the material after application. Upon evaporation, it bonds the film-forming components together to produce a uniform application.
- Solvents provide heat transfer on modified sheets in cold-adhesive applications.

The chart below provides examples of imposed limits for specific categories. (Note: A typical roof coating has a weight of 8 pounds per gallon to 8.5 pounds per gallon. This

would indicate the solids content [weight of material after solvent evaporation] would be approximately 70 percent.)

Cold-Applied Coatings Solvent Content

| Coating Category | Limit (grams of VOCs/liter) | Limit (lbs of VOCs/gallon) |
|-----------------------|-----------------------------------|----------------------------------|
| Varnish | 350 | 2.92 |
| Lacquer | 680 | 5.67 |
| Waterproofing sealers | 400 | 3.34 |
| Roof coatings | 300 | 2.50 |
| Waterproof mastics | 300 | 2.50 |

Research continues in providing alternative solutions to solvent requirements. As we enter the new millennium, we must also be cognizant of the depleting resources that we will have available to us. This, more than any other factor, will dictate what materials will be used throughout this century.

Water-Based Adhesives

The concerns regarding VOCs in solvent-based products have increased the use of water-based adhesives. The waterborne products are permanent roof materials, which are environmentally friendly because they do not contain solvents- -organic or inorganic. Waterborne products use water and stabilizing clays other than petroleum or other distilled solvents.

Asphalt emulsions are manufactured by dispersing small droplets of asphalt bitumen in water. The manufacturing process is to mix the bitumen at a heated temperature at which it will become a free-flowing liquid (from 320°F to 350°F) with a mixture of water (at boiling point 180°F) and an emulsifying agent or clay, such as bentonite. The elevated temperature of the water blends with the asphalt, and the water cures.

The manufacturing process of modified bitumen adhesive (SEBS) is similar to the emulsion process except polymers, such as rubber, are added to the asphalt. The modified asphalt blend is mixed with water and clay stabilizers. Waterborne products cure with heat; the greater the heat the quicker the cure time. In contrast to solvent-based products, humidity slows down the curing process.

Successful cold-process adhesives, solvent-based and water-based require a good asphalt bitumen blend to manufacture a good product providing the manufacturer also adds a good polymer. The asphalt used is refinery crude oil asphalt that has multiple blends of materials. An adhesive manufacturer can control the type of asphalt it obtains from the refinery by specifying the properties that it wants the crude oils and blend asphalts to meet. The important physical properties are softening point, penetration and

ductility. Higher-penetration asphalts and modified asphalts are softer than low-penetration asphalts. Asphalt testing can be completed by conducting ASTM D-36: The Ring and Ball Test.

Reinforcements

As noted earlier, the adhesives used in cold-applied systems offer little waterproofing capacities. The waterproofing is provided by the reinforcements. There are four reinforcements that are used in cold-process systems:

1. Fiberglass felt plies
2. Fiberglass scrim
3. Spunbonded polyester mats
4. Stitchbonded polyester mats

Fiberglass felts were introduced in the United States in the late 1940s. They are used in cold-process systems in the same manner as in BUR systems in multiple-ply configurations. Fiberglass felts are manufactured with filaments, which are derived from molten glass streams through tiny orifices that are made of precious metals. The molten glass is taken from batches of sand, limestone and soda ash, which are continuously deposited into a furnace that is heated above 2500°F. The fiberglass filaments, which have long cross-sections of 12 inches to 15 inches, are bound with a thermosetting binder, phenol-formaldehyde, urea-formaldehyde or acrylic resin. Most fiberglass felts are isotropic, which means they have equivalent properties in longitudinal and transversal strength.

The advantages of fiberglass felts include exceptional tensile strength (in longitudinal and transversal directions), an inherent resistance to moisture and a greater resistance to splitting than organic felts. When used in cold-applied applications, fiberglass felt must be cut from a roll and laid in a relaxed state for approximately half an hour prior to application. The material's natural memory tendency promotes ridging in these applications if this procedure is not followed. This condition occurs because the curing process of cold-applied systems is substantially longer than hot-applied systems, which cure instantaneously.

Polyester has been well-accepted as reinforcement in cold-process systems. Originally developed in the United States, these reinforcements are made of mats that weigh between 1 ounce and 3 ounces. These reinforcements can be adhered with solvent-based and waterborne adhesives. The combined advantages of a cold-process system with the physical attributes of polyester fabrics offer the following advantages:

- Exceptional elongation and recovery
- Toughness and flexibility
- Low shrinkage
- Impressive tear strength
- Puncture resistance

- Resistance to moisture, chemicals and ultraviolet light
- Lightweight
- Pliability

There are two common polyester mats used as reinforcements in cold-process systems: spunbonded polyester mats and stitchbonded polyester mats. Stitchbonded polyester mats are manufactured with fibers that vary in size from 1 inch to 3 inches, which are formed into nonwoven fiber mats. A chemical binder is added to the fibers to improve the strength of the mat. The result is a nonisotropic (unequal characteristics in all directions) tissue with a ratio between longitudinal and transversal strength of 80-to-20 to 60-to-40.

Spunbonded polyester mats are manufactured from endless filaments that are spun and immediately laid into a nonwoven mat. The mat can then be stitched together and reinforced by a binder or reinforced by thermally melting the filaments together. The result is an isotropic tissue, which means the properties in all directions are nearly equal.

There are three types of reinforcements used in cold-adhesive systems:

1. SBS-modified sheets
2. APP-modified sheets
3. Chloroprene rubber modified sheets

The waterproofing agent in these configurations is the reinforcement sheet; therefore, it is essential that the adhesive and reinforcement sheet are compatible. Different adhesives do not work with all reinforcements. For instance, it has been determined that waterborne adhesives do not perform well with fiberglass felts because these sheets do not saturate well. Waterborne products should be applied over synthetic nonwoven mats, such as polyester, that will allow for the water to properly migrate through the porous mats allowing for proper curing to take place.

The same is true for modified sheets used in cold-adhesive systems. Each manufacturer promotes adhesives that are specifically designed to work with its reinforcement felts. In recent years, manufacturers have invested more time in researching the effects of the relationship between adhesives and reinforcements. It is safe to say that a number of projects completed in the past using adhesives and modified sheets were completed with little real knowledge of actual performance or capabilities.

Test Procedures

Roof membrane testing was conducted to evaluate potential changes in long-term waterproofing capabilities of cold-applied systems. The initial testing included three representative roof system samples constructed in the following manner:

- Sample A:** Four plies of polyester reinforcement with solvent-based adhesive
Sample B: Two plies of SBS-modified bitumen reinforcement with solvent-based adhesive
Sample D: Four plies of polyester reinforcement with water-based adhesive

Test Material Specifications

Polyester reinforcement: Stitchbonded polyester reinforcing fabric

| | | |
|-------------|-------------|-----------------------|
| Weight: | ASTM D 1177 | 3 oz./YD ² |
| Tensile: | ASTM D 1682 | 57.1 lbs |
| Elongation: | ASTM D 1682 | 61.65% |

SBS-modified reinforcement: Styrene-butadiene-styrene (SBS) rubber modified asphalt membrane reinforced with nonwoven polyester mat

| | | |
|-------------|-------------|---------|
| Tensile: | ASTM D 6164 | 125 lbs |
| Elongation: | ASTM D 6164 | 50 % |

Water-based adhesive: Single component, clay-stabilized asphalt emulsion base modified with SEBS rubber

| | | |
|-------------------|--------------------------------------|----------|
| Weight/gallon: | ASTM D 1475 | 9.2 lbs. |
| Solids content | ASTM D 2697 | |
| | by weight: | 45-50% |
| | by volume: | 55-60% |
| Application rate: | 1.5 to 2 gallons per 100 square feet | |

Solvent based adhesive: SBS-modified bitumen adhesive blend of processed asphalt, polymers, solvent and nonasbestos fillers

| | | |
|-------------------|--------------------------------------|---------|
| Weight/gallon: | ASTM D 3019 | 8.4 lbs |
| Application rate: | 1.5 to 2 gallons per 100 square feet | |

Cold-process adhesive: Blend of refined cutback asphalt, nonasbestos fiber fillers and bonders

| | | |
|-------------------|--------------------------------------|---------|
| Weight/gallon: | ASTM D 4479-95 | 8.8 lbs |
| Application rate: | 1.5 to 2 gallons per 100 square feet | |

The roof membrane samples used for these tests were constructed in accordance with proper application procedures. The representative samples were constructed on a

rooftop and allowed to cure in the elements for 25 days. The average temperature during the curing process was 78°F. Large samples of each representative system were constructed and divided into four equal segments. The object of the testing was to evaluate the differences between the two types of adhesive, solvent-based and water-based, within the two system categories: cold process and cold adhesive.

Manufacturer's system components (adhesive and membrane) were chosen randomly and analyzed by the following testing methods:

1. Heat conditioning testing
2. Cold conditioning testing
3. Water immersion testing

At the conclusion of the testing time period, the samples were analyzed through the following observation and testing procedures:

1. Visual observation of topical and cross-sectional surface
2. Microscopic analysis of adhesive materials and membrane
3. Tensile testing (load/strain) ASTM D 2523
4. Pliability tests ASTM D 146
5. Peel resistance at different temperatures
6. Peel resistance after immersion in water

Control Sample Data

A control sample for each representative sample (Samples A, B and D) of each system configuration (6 inches wide by 12 inches in length) was tested at the end of the curing process to establish criteria with which the tested data would be compared. The data for the control sample follows:

| CONTROL SAMPLE | LENGTH | WIDTH | THICKNESS | WEIGHT | TENSILE STRAIN AVG. |
|-------------------|--------|-------|-----------|--------|------------------------|
| A | 12" | 6" | 3.435 mm | 118 kg | 170% |
| B | 12" | 6" | 6.108 mm | 288 kg | 203% |
| D | 12" | 6" | 0.922 mm | 37 kg | 179% |

Heat Conditioning Testing

One representative sample (Samples A, B and D) of each system configuration (6 inches wide by 12 inches in length) was placed in an oven for 35 days at constant temperature of 160°F. The testing was conducted in accordance with ASTM D 5869-95, "Standard Practice for Dark Oven Heat Exposure of Bituminous Materials". The testing was conducted with reference to Item 8.1: Expose the specimens in a forced-ventilation oven at 158°F + or - 5°F and Item 8.3(1): 35 + or - 0.25 consecutive days.

The purpose of this test was to determine what properties are affected by heat exposure as a material ages in service.

| HEAT CONDITIONING TESTING | LENGTH | WIDTH | THICKNESS | WEIGHT | TENSILE STRAIN STRENGTH |
|---------------------------------|--------|---------|-----------|--------|-------------------------------|
| A | 11.25" | 5-5/16" | 2.98 mm | N/A | too brittle to test |
| B | 11.25" | 5.50" | 2.60 mm | N/A | too brittle to test |
| D | 11.25" | 5.50" | 0.695 mm | 10 kg | too brittle to test |

Visual Observation of Samples

Sample A: The sample exhibited a volumetric change of properties through heat conditioning testing. There was a decrease in the sample's dimensional shape (length and width) and a decrease in thickness and weight. Sample was extremely brittle with characteristics of hot-applied asphalt BUR materials. Reinforcement mat scrim was evident in top surfacing. This occurrence can be attributed to a breakdown of the adhesive properties. This indicates the necessity of a surface coating for these systems. No other surface deficiencies were noted. Adhesion was excellent throughout the ply configuration. The sample bonded to the metal oven tray, further indicating strong adhesive properties. The desired thinner film application was achieved. Material exhibited low elastomeric properties; no tensile testing could be completed because of the brittle material state. The tested sample failed ASTM D 146 Section 14 pliability test. The results of the tests were instant cracks.

Sample B: The sample exhibited a volumetric change of properties through the heat conditioning testing. There was a decrease in the sample's dimensional shape (length and width) and a decrease in thickness and weight. Sample was slightly brittle with characteristics of hot-applied asphalt BUR materials. The top sample surfacing indicated substantial blistering. Cross-sectional view of the sample indicated that deficiencies were promoted by adhesive migration. (Theory: Occurrence was because of accelerated evaporation of solvents.) This condition was observed in the early stages of heat conditioning; within the first two days of placement in the oven, the condition subsided throughout the remaining test period. Adhesion was excellent throughout the ply configuration. The sample bonded to the metal oven tray, further indicating strong adhesive properties. The desired thinner film application was achieved. No reinforcement deficiencies were noted. Membrane adhesive properties

were fully elastomeric. Reinforcement properties were fully elastomeric. The tested sample passed ASTM D 146 Section 14 pliability test.

Sample D: The sample exhibited a volumetric change of properties through the heat conditioning testing. There was a decrease in the sample's dimensional shape (length and width) and a decrease in thickness and weight. Sample was extremely brittle. Reinforcement mat scrim was evident in top surfacing. This occurrence can be attributed to a breakdown of the adhesive properties. This indicates the necessity of a surface coating for these systems. No other surface deficiencies were noted. Adhesion was excellent throughout the ply configuration. The desired thinner film application was achieved. Material exhibited low elastomeric properties; no tensile testing could be completed because of brittle material state. Tested sample failed ASTM D 146 Section 14 pliability test. The results of the tests were instant cracks.

Comments on Heat Conditioning Tests

The heat conditioning testing indicated that cold-applied systems might experience a change in properties after volatiles dissipate. There is also an indication that solvent-based cold adhesives can harden and become brittle. The crystallization process may indicate that cold-applied adhesives, when exposed to heat, may gain some similar properties to blown asphalt. Further testing should be conducted to determine whether the cold-applied adhesives also inherit blown asphalts waterproofing capabilities or whether they are only restricted to adhesion capacities.

The pliability test failures of the solvent-based polyester reinforcement (Sample A) and the water-based polyester reinforcement (Sample D) raises substantial concerns. Further testing should be conducted to determine the effects of a top surface seal coating, required in these applications but not used in the testing, would have had on the performance capacity of these materials in heat conditioning.

Cold Conditioning Testing

One representative sample (Samples A, B and D) of each system configuration (6 inches wide by 12 inches in length) was placed in a freezer for 35 days at constant temperature of 30°F. The purpose of this test was to determine what properties are affected by cold exposure as a material ages in service.

| COLD CONDITIONING TESTING | LENGTH | WIDTH | THICKNESS | WEIGHT | TENSILE STRAIN STRENGTH |
|---------------------------------|--------|-------|-----------|--------|-------------------------------|
| A | 11.75" | 5.75" | 2.385 mm | 130 kg | 305% |
| B | 11.50" | 5.75" | 6.535 mm | 335 kg | 390% |
| D | 11.75" | 5.75" | 1.390 mm | 45 kg | 347% |

Visual Observation of Samples

The cold conditioning test protocol was established because of the concern about cure time in colder climates and what effect latent moisture solvents in a system may have on the physical properties of the roof membrane system. We are trying to identify the application window for cold-applied systems.

Sample A: The sample exhibited a volumetric change of properties through the cold conditioning testing. There was a slight decrease in the sample's dimensional shape (length and width) and a decrease in thickness and increase in weight. The decrease in thickness may indicate the material has the ability to cure in colder temperatures. The additional weight can be attributed to a gain in moisture content. No membrane surface deficiencies were noted. Adhesion was excellent throughout the ply configuration. The desired thinner film application was achieved. No reinforcement deficiencies were noted. Membrane adhesive properties were fully elastomeric. Reinforcement properties were fully elastomeric. The tested sample passed ASTM D 146 Section 14 pliability test.

Sample B: The sample exhibited a volumetric change of properties through the cold conditioning testing. There was a slight decrease in the sample's dimensional shape (length and width) and an increase in thickness and weight. The additional weight can be attributed to a gain in moisture content. No membrane surface deficiencies were noted. Adhesion was excellent throughout the ply configuration. No reinforcement deficiencies were noted. Membrane adhesive properties were fully elastomeric. Reinforcement properties were fully elastomeric. The tested sample passed ASTM D 146 Section 14 pliability test.

Sample D: The sample exhibited a volumetric change of properties through the cold conditioning testing. There was a slight decrease in the sample's dimensional shape (length and width) and an increase in thickness and weight. The additional weight can be attributed to a gain in moisture content. Reinforcement mat scrim was evident in top surfacing. This may be an indication of a breakdown of the adhesive properties. Further testing should be conducted to evaluate the waterproofing capabilities of these products in cold conditioning. There were no other noted deficiencies. Adhesion was excellent throughout the ply configuration. Membrane adhesive properties were fully elastomeric. Reinforcement properties were fully elastomeric. The tested sample passed ASTM D 146 Section 14 pliability test.

Comments on Cold Conditioning Tests

The cold age testing indicated that cold-applied materials have the capacity to properly cure in cold conditioning. The adhesion and elastomeric properties of all samples were

excellent after the cold conditioning period. There is some concern with the visibility of the reinforcement mat scrim with the water-based products, and more testing in this area is required. However, the test results indicate that each system may possess sufficient properties in cold climates.

Water Immersion Testing

One representative sample (Samples A, B and D) of each system configuration (6 inches wide by 12 inches in length) was immersed in water for 35 days at constant temperature of 72°F. The purpose of this test was to determine what properties are affected by water exposure as a material ages in service.

| WATER IMMERSION TESTING | LENGTH | WIDTH | THICKNESS | WEIGHT | TENSILE STRAIN |
|-------------------------------|--------|----------|-----------|--------|-------------------|
| A | 12" | 5-13/16" | 2.480 mm | 155 kg | 318% |
| B | 11.50" | 5-12/16" | 6.725 mm | 365 kg | 404% |
| D | 11.75" | 5-12/16" | 1.080 mm | 60 kg | 336% |

Visual Observation of Samples

Sample A: The sample exhibited a volumetric change of properties through the water immersion testing. The dimensional shape of the sample remained virtually unchanged in length and width. There was a decrease in thickness and an increase in weight. The additional weight can be attributed to a gain in moisture content. Reinforcement mat scrim was evident in top surfacing. This may be an indication of a breakdown of the adhesive properties. The top surfacing exhibited a discoloration typical of membrane systems in ponded areas. No other membrane surface deficiencies were noted. Adhesion was excellent throughout the ply configuration. The desired thinner film application was achieved. Membrane adhesive properties were fully elastomeric. Reinforcement properties were fully elastomeric. The tested sample passed ASTM D 146 Section 14 pliability test.

Sample B: The sample exhibited a volumetric change of properties through the water immersion testing. There was a slight decrease in the sample's dimensional shape (length and width) and an increase in thickness and weight. The additional weight can be attributed to a gain in moisture content. The top surfacing exhibited a discoloration typical of modified bitumen membrane systems in ponded areas. No other membrane surface deficiencies were noted. Adhesion was excellent throughout the ply configuration. Membrane adhesive properties were fully elastomeric. Reinforcement properties were fully elastomeric. The tested sample passed ASTM D 146 Section 14 pliability test.

Sample D: The sample exhibited a volumetric change of properties through the water immersion testing. The dimensional shape of the sample remained virtually unchanged in length and width. There was a decrease in thickness and an increase in weight. The additional weight can be attributed to a gain in moisture content. The top surfacing exhibited a discoloration typical of membrane systems in ponded areas. No other membrane surface deficiencies were noted. Adhesion was excellent throughout the ply configuration. The desired thinner film application was achieved. Membrane adhesive properties were fully elastomeric. Reinforcement properties were fully elastomeric. The tested sample passed ASTM D 146 Section 14 pliability test.

Comments on Water Immersion Tests

The water immersion testing indicated that the properties of all tested cold-applied materials remain unchanged in these conditions. Membrane discoloration typically associated with all membrane systems in ponded water conditions was noted on each sample. The discoloration appeared to only have a esthetic ramifications because the adhesion and elastomeric properties of all samples were excellent. Nevertheless, it is critical that proper slope requirements are maintained in the installation of these systems. The slope requirements should be based on the reinforcement sheets slope parameters.

Microscopic Analysis of Adhesive Materials and Membranes

Microscopic analysis of each representative sample was conducted at the conclusion of each test period compared with the control samples. Microscopic photographs illustrate the modifications of the materials. Microscopic examination was utilized to define enhanced behavior modifications not detected in visual observations.

Sample A: The microscopic examination indicated a change in the material properties throughout the conditioning testing. The water immersion sample illustrated deep fissures in the adhesive structure. The fissures do not depict the reinforcement mat- - the breakdown of properties appears to be concentrated within the adhesive. These illustrations are in direct correlation of the findings of this same at the water immersion test. Minor fissures were observed at the cold conditioning sample.

Sample B: The microscopic examination concluded that there was relatively no change in the membrane composition throughout the conditioning testing. The only variation detected was loss of surface granules in the water immersion sample. The control sample, heat conditioning sample and cold conditioning sample are almost identical. These observations are in direct correlation with the results of the condition sample tests.

Sample D: The microscopic examination indicated a change in the material properties throughout the conditioning testing. Loss of adhesive structure and clearly defined reinforcement mat were illustrated at the cold conditioning and water immersion testing. The loss of adhesive structure was most evident at the cold conditioning test. These observations are in direct correlation with the results of the condition sample tests. The adhesive structure illustrated in the microscopic examination of the water-based adhesive samples is clearly divergent from the solvent-based samples.

Tensile Tests

Tensile tests were conducted in accordance with ASTM D 2523: "Standard Practice for Testing Load-Strain Properties of Roofing Membranes". The purpose of the testing is to determine the load/strain properties of the roof membrane systems at various temperatures. Three tests were conducted from each representative sample. Strain was determined through the following equation:

$$s = 100(c - c_0)/c_0$$

where:

s = specimen strain, %

c₀ = distance between reference marks before application of load (constant 1.5" for these tests)

c = distance between reference marks at a given load

TENSILE TEST RESULT DATA

| COLD CONDITIONING TESTING | LOAD DISTANCE | STRAIN % |
|---------------------------|---------------|----------|
| A-1 | 5.903" | 294% |
| A-2 | 5.643" | 276% |
| A-3 | 6.685" | 346% |
| B-1 | 7.147" | 376% |
| B-2 | 7.694" | 413% |
| B-3 | 7.228" | 382% |
| D-1 | 6.936" | 362% |
| D-2 | 7.247" | 383% |
| D-3 | 5.931" | 295% |

| WATER IMMERSION TESTING | LOAD DISTANCE | TENSILE STRAIN |
|-------------------------|---------------|----------------|
| A-1 | 6.103" | 307% |
| A-2 | 6.682" | 345% |
| A-3 | 6.044" | 303% |
| B-1 | 8.035" | 435% |
| B-2 | 7.150" | 377% |
| B-3 | 7.499" | 400% |
| D-1 | 6.936" | 362% |
| D-2 | 6.059" | 304% |
| D-3 | 6.640" | 343% |

Observation of Tensile Tests

Tensile tests were conducted on the cold-conditioned and water immersion samples. The heat conditioning samples proved to be too brittle to conduct adequate testing. Test results indicated that the load values were low. The strain percentages (elongation) were excellent. Material engineering analysis quantifies that materials that exhibit high modulus properties illustrate lower load capacities. The elongation properties exhibited here are significantly better than built-up systems utilizing blown asphalt.

Peeling Resistance

One physical attribute that cold-applied materials must maintain is their ability to effectively bond the reinforcement. The adhesive properties of the material must withstand the elements over the service life of a system. The tests conducted simulate weather exposures of heat, cold and precipitation, which are common elements these systems must withstand during their service lives. The peeling resistance tests were conducted to determine how adhesive properties are affected by these elements as a material ages in service.

PEELING RESISTANCE AT DIFFERENT TEMPERATURES

| SAMPLE | HEAT CONDITIONING | COLD CONDITIONING |
|--------|----------------------|----------------------|
| A-1 | Excellent | Excellent |
| A-2 | Excellent | Excellent |
| A-3 | Excellent | Excellent |
| B-1 | Excellent | Good |
| B-2 | Excellent | Good |
| B-3 | Excellent | Excellent |
| D-1 | Excellent | Excellent |
| D-2 | Excellent | Excellent |
| D-3 | Excellent | Excellent |

PEELING RESISTANCE AFTER WATER IMMERSION

| SAMPLE | WATER IMMERSION |
|--------|--------------------|
| A-1 | Excellent |
| A-2 | Excellent |
| A-3 | Excellent |
| B-1 | Good |
| B-2 | Good |
| B-3 | Good |
| D-1 | Excellent |
| D-2 | Excellent |
| D-3 | Excellent |

Test Observations

The completed tests indicated that cold adhesives possess properties that are advantageous to long-term adhesion capabilities. The main function of adhesive is to promote adhesion or bonding of reinforcement. The tests concurred that these materials demonstrated the proper bonding mechanism as a thin film was noted at all samples in each conditioning test. Excellent adhesive properties were exhibited by all the representative samples. The testing also indicated that solvent-based adhesives might possess similar properties to blown asphalt systems. This was demonstrated in the crystallization of the adhesive in the heat conditioning testing.

Comparative Test Results are as Follows:

| Sample | Control | | | | Heat Conditioning | | | | Cold Conditioning | | | | Water Immersion | | | |
|--------|---------|---|------|-----|-------------------|------|------|-----|-------------------|------|------|-----|-----------------|------|------|-----|
| | L | W | T | Wt | L | W | T | Wt | L | W | T | Wt | L | W | T | Wt |
| A | 12 | 6 | 3.44 | 118 | 11.3 | 5.31 | 2.98 | n/a | 11.3 | 5.75 | 2.39 | 130 | 12 | 5.81 | 2.48 | 155 |
| B | 12 | 6 | 6.11 | 288 | 11.3 | 5.5 | 2.6 | n/a | 11.5 | 5.75 | 6.54 | 335 | 11.5 | 5.75 | 6.73 | 365 |
| D | 12 | 6 | 0.92 | 37 | 11.3 | 5.5 | 0.7 | 10 | 11.8 | 5.75 | 1.39 | 45 | 11.8 | 5.75 | 1.08 | 60 |

L = Length in inches
W = Width in inches

T = Thickness in mm
Wt = Weight in kg

The testing proved to be an important initial procedure. Most cold-applied writings in the United States have centered on the systems, advantages and disadvantages for installation. There has not been an emphasis on the long-term performance characteristics. These issues are more vital to the continued use or nonuse of these systems. If they do not provide long-term waterproofing capabilities, their installation advantages are moot points.

At this time, no manufacturers are able to qualify in specific terms what physical and chemical changes take place through the use of cold adhesives and reinforcements. It can also be stated that some systems' installed in recent years were completed with little knowledge of the systems performance capabilities.*

Based on our observations of the initial test procedures, we have determined further testing is required. It is our decision to continue the testing procedures of these systems. Further testing will include the following items:

1. Heat conditioning and cold conditioning tests at extended time periods.
2. Increase in number of tensile tests completed on conditioned samples to report load/strain percentage.
3. Field performance testing of installed roof systems of various ages and geographic climates. Project lists will be solicited from manufacturers.
4. Develop a mathematical modeling chart to statically forecast system lifespan.
5. Testing will be conducted on multiple manufacturers' systems for cold-process systems with solvent-based and water-based adhesives and cold-adhesive systems with solvent-based and water-based adhesives.

The results of these tests will be published and presented to the industry at the conclusion of the testing period.

* Statement made by former technical director and cold system researcher of cold roof system manufacturer